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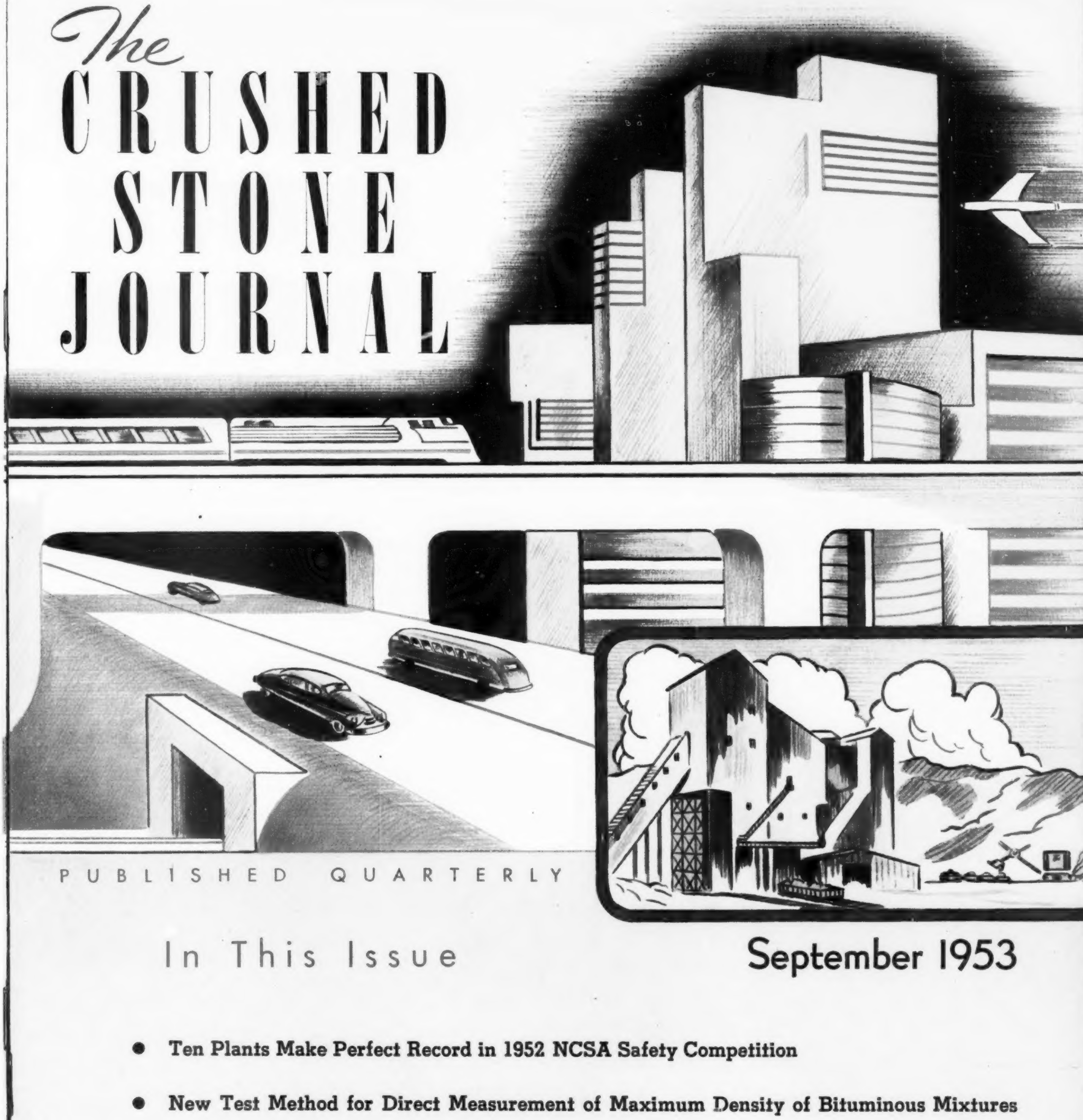

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Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

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THE CRUSHED STONE JOURNAL

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Ten Plants Make Perfect Record in 1952 NCSA Safety Competition

By **ELIZABETH K. ELSNER**
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THE injury experience at operations enrolled in the National Crushed Stone Association Safety Competition of 1952, while not so favorable as in 1951, was one of the best in the 27-year history of the contest, according to the Bureau of Mines, United States Department of the Interior. Although the injury record of the competing operations has not been improved in each competition year, a decidedly progressive improvement has been shown over the 27-year span of the contest. The injury frequency rate of 21.193 per million man-hours of exposure to hazard in 1952 was lower in only 6 of the past contest years and the injury severity rate of 3.514 days lost per thousand man-hours was the sixth lowest rate recorded since the beginning of the contest in 1926.

The Winning Operation

Highest safety honors were won by the Bakerton underground limestone mine of The Standard Lime and Stone Company at Bakerton, Jefferson County, West Virginia, for having operated a total of 177,946 man-hours during the year without a lost-time disabling injury. For this outstanding safety accomplishment, a bronze plaque provided by the Explosives Engineer Magazine was won by this plant, and in recognition of the part which the employees at this plant had in making this safety record possible, each is awarded a symbolic certificate by the National Crushed Stone Association. The Bakerton mine enrolled in this competition in 1946 and, except in 1950, has engaged actively in the contests. During its 6 years of participation it has operated a total of 744,888 man-hours with but 6 lost-time injuries and 219 days loss of injury disability. The frequency and severity rates during its years of competing were 8.05 and 0.29 respectively, each well below the 27-year contest averages and the averages for any year in which the plant was a competitor for top honors. The employees and supervisors at the Bakerton operation have proved the value of joint cooperation in well-organized and efficient safety programs designed to promote safety working conditions and practices.

The Security limestone quarry of the North American Cement Corporation at Hagerstown, Washington County, Maryland, ranked in second place in the 1952 contest with the outstanding achievement of being worked 169,133 man-hours without any lost-time disabling injuries. In third place in the competition was the North Branford No. 7 trap rock quarry of The New Haven Trap Rock Company at North Branford, New Haven County, Connecticut, by virtue of having no disabling injuries during a work-time of 129,945 man-hours. The fourth ranking operation was White Haven sandstone quarry of The General Crushed Stone Company at White Haven, Luzerne County, Pennsylvania. This plant was operated 95,186 man-hours during 1952 without having a lost-time injury.

TABLE I

RELATIVE STANDING OF QUARRIES IN THE 1952 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE INJURY-SEVERITY RATES OF THE QUARRIES [1]

Rank	Man-hours worked	Number of injuries [2]					Average days of disability per temp. injury	Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
		F.	P.T.	P.P.	Temp.	Total		F.	P.T.	P.P.	Temp.	Total		
2	169,133	—	—	—	—	—	—	—	—	—	—	—	0.000	0.000
3	129,945	—	—	—	—	—	—	—	—	—	—	—	.000	.000
4	95,186	—	—	—	—	—	—	—	—	—	—	—	.000	.000
5	80,518	—	—	—	—	—	—	—	—	—	—	—	.000	.000
6	70,440	—	—	—	—	—	—	—	—	—	—	—	.000	.000
7	68,939	—	—	—	—	—	—	—	—	—	—	—	.000	.000
8	62,167	—	—	—	—	—	—	—	—	—	—	—	.000	.000
9	59,410	—	—	—	—	—	—	—	—	—	—	—	.000	.000
10	31,737	—	—	—	—	—	—	—	—	—	—	—	.000	.000
11	102,000	—	—	—	1	1	1	—	—	—	1	1	9.804	.010
12	83,200	—	—	—	2	2	3	—	—	—	5	5	24.038	.060
13	142,200	—	—	—	3	3	5	—	—	—	14	14	21.097	.098
14	78.899	—	—	—	2	2	5	—	—	—	10	10	25.349	.127
15	360,582	—	—	—	2	2	25	—	—	—	50	50	5.547	.139
16	66,366	—	—	—	1	1	10	—	—	—	10	10	15.068	.151
17	112,050	—	—	—	1	1	24	—	—	—	24	24	8.925	.214
18	168,780	—	—	—	3	3	14	—	—	—	42	42	17.775	.249
20	269,117	—	—	—	4	4	20	—	—	—	78	78	14.863	.290
21	138,350	—	—	—	1	1	53	—	—	—	53	53	7.228	.383
24	85,384	—	—	—	3	3	16	—	—	—	47	47	35.135	.550
25	385,160	—	—	—	29	29	8	—	—	—	229	229	75.293	.595
26	455,639	—	—	1	2	3	12	—	—	300	24	324	6.584	.711
27	96,516	—	—	—	2	2	38	—	—	—	76	76	20.722	.787
28	199,733	—	—	—	3	3	54	—	—	—	161	161	15.020	.806
29	301,808	—	—	—	9	9	27	—	—	—	247	247	29.820	.818
30	75,428	—	—	—	1	1	76	—	—	—	76	76	13.258	1.008
31	28,266	—	—	—	1	1	29	—	—	—	29	29	35.378	1.026
32	96,498	—	—	—	7	7	16	—	—	—	115	115	72.540	1.192
33	79,867	—	—	—	2	2	48	—	—	—	96	96	25.042	1.202
35	68,800	—	—	—	4	4	44	—	—	—	175	175	58.140	2.544
36	61,342	—	—	—	5	5	43	—	—	—	217	217	81.510	3.538
38	115,734	—	—	1	9	10	21	—	—	750	185	935	86.405	8.079
39	702,053	1	—	—	8	9	23	6,000	—	—	186	6,186	12.820	8.811
40	54,387	—	—	1	1	2	120	—	—	624	120	744	36.733	13.680
41	150,060	1	—	—	4	5	6	6,000	—	—	24	6,024	33.320	40.144
42	34,155	1	—	—	1	2	2	6,000	—	—	2	6,002	58.557	175.728
Totals and rates:														
1952	5,279,849	3	—	3	111	117	21	18,000	—	1,674	2,296	21,970	22.160	4.161
1951	5,441,304	1	—	4	100	105	24	6,000	—	6,325	2,381	14,706	19.297	2.703

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

Injury-Free Operations

The following 10 operations attained injury-free records in 1952 and in recognition of their achievements, receive Certificates of Honorable Mention from the National Crushed Stone Association. The 10 operations, including the trophy winner, were operated 945,421 man-hours or 15 per cent of the total worktime of all plants enrolled in the competition:

Bakerton mine, The Standard Lime and Stone Company, Bakerton, Jefferson County, West Virginia; 177,946 man-hours.

Security quarry, North American Cement Corporation, Hagerstown, Washington County, Maryland; 169,133 man-hours.

North Branford No. 7 quarry, The New Haven Trap Rock Company, North Branford, New Haven County, Connecticut; 129,945 man-hours.

White Haven quarry, The General Crushed Stone Company, White Haven, Luzerne County, Pennsylvania; 95,186 man-hours.

Rock Hill quarry, The General Crushed Stone Company, Quakertown, Bucks County, Pennsylvania; 80,518 man-hours.

Stephens City quarry, M. J. Grove Lime Company, Stephens City, Frederick County, Virginia; 70,440 man-hours.

Jordanville quarry, The General Crushed Stone Company, Jordanville, Herkimer County, New York; 68,939 man-hours.

Cedar Hollow quarry, Warner Company, Devault, Chester County, Pennsylvania; 62,167 man-hours.

Wallingford No. 1 quarry, The New Haven Trap Rock Company, Middlefield, New Haven County, Connecticut; 59,410 man-hours.

Prospect Stone Plant No. 6 quarry, Eastern Rock Products, Incorporated, Prospect, Oneida County, New York; 31,737 man-hours.

Statistics of the Competition

The over-all safety record at the 42 operations enrolled in the 1952 competition was better than the average for the 27 years of the contest. Thirty-six open quarries completed the year's contest with an injury frequency rate of 22.16 per million man-hours and a severity rate of 4.16 days per thousand man-hours. Although these rates were not so favorable as the respective rates of 19.30 and 2.70 in the 1951 competition, they were nevertheless consistent with the long term improvement made since the origination of the competition.

The injury frequency rate at the 6 competing mines was 16.70 and the severity rate was 0.513, each better than its corresponding rate in the 1951 contest. The 1952 frequency rate was 11 per cent lower than the previous year's rate, 46 per cent lower than the 27-year average rate for this group, and the fourth best rate in the history of the contest among similar operations. Also, the 1952 severity rate followed a similar pattern, but was more pronounced in some respects. The rate dropped 68 per cent in 1952 compared with 1951, it was 87 per cent lower than the 27-year average, and the fourth less severe in the entire history of the competition. The over-all injury experience at underground mines in 1952 was better than in any year since record rates were established in 1938.

Fourteen states were represented in the 1952 competition. These were: New York, 11; Pennsylvania, 7; Virginia, 6; Connecticut, 3; Maryland, Massachusetts, Ohio, Texas, and West Virginia, 2 each; and single operations in Illinois, Kentucky, Michigan, Oklahoma, and Tennessee.

Injury Data

Of the injuries with stated causes at the participating plants in 1952, falls of persons resulted in 19 disabilities or more injuries than from any other cause. This type of injury represented 16 per cent of the total accidents with reported causes. Accidents involving the handling of materials resulted in 14 per cent of the total, 13 per cent were

TABLE II

RELATIVE STANDING OF UNDERGROUND MINES IN THE 1952 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE INJURY-SEVERITY RATES OF THE MINES[1]

Rank	Man-hours worked	Number of injuries[2]					Average days of disability per temp. injury	Number of days of disability[2]					Frequency rate[3]	Severity rate[3]
		F.	P.T.	P.P.	Temp.	Total		F.	P.T.	P.P.	Temp.	Total		
1	177,946	—	—	—	—	—	—	—	—	—	—	—	0.000	0.000
19	289,369	—	—	—	3	3	28	—	—	—	84	84	10.367	.290
22	131,833	—	—	—	1	1	55	—	—	—	55	55	7.585	.417
23	383,721	—	—	—	2	2	94	—	—	—	187	187	5.212	.487
34	132,180	—	—	—	10	10	17	—	—	—	168	168	75.654	1.271
37	22,400	—	—	—	3	3	30	—	—	—	89	89	133.929	3.973
Totals and rates:														
1952	1,137,449	—	—	—	19	19	31	—	—	—	583	583	16.704	0.513
1951	1,179,458	—	—	1	21	22	39	—	—	1,125	818	1,943	18.653	1.647

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

TABLE III

YEARLY SUMMARY—QUARRIES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1926–52 [1]

Year	Plants	Man-hours worked	Number of injuries [2]					Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
			F.	P. T.	P. P.	Temp.	Total	F.	P. T.	P. P.	Temp.	Total		
1926	40	5,298,983	3	—	6	207	216	18,000	—	9,000	4,239	31,239	40.763	5.895
1927	48	7,876,791	9	—	2	458	469	54,000	—	2,100	7,186	63,286	59.542	8.034
1928	53	7,509,098	8	—	4	322	334	48,000	—	8,700	5,493	62,193	44.479	8.282
1929	53	7,970,325	4	—	5	286	295	24,000	—	5,760	5,533	35,293	37.012	4.428
1930	68	8,013,415	6	—	9	227	242	36,000	—	7,250	3,671	46,921	30.199	5.855
1931	58	5,085,857	4	—	13	198	215	24,000	—	18,660	3,540	46,200	42.274	9.084
1932	40	2,661,850	1	—	4	75	80	6,000	—	6,750	2,481	15,231	30.054	5.722
1933	40	2,704,871	1	—	1	67	69	6,000	—	48	2,893	8,941	25.510	3.306
1934	46	3,288,257	1	—	2	106	109	6,000	—	2,850	1,873	10,723	33.148	3.261
1935	46	4,166,306	2	1	8	77	88	12,000	6,000	9,900	3,015	30,915	21.122	7.420
1936	50	6,399,023	5	—	14	182	201	30,000	—	8,168	4,590	42,758	31.411	6.682
1937	47	6,199,001	7	—	9	136	152	42,000	—	5,875	4,461	52,336	24.520	8.443
1938	47	4,658,119	2	—	6	76	84	12,000	—	6,600	3,184	21,784	18.033	4.677
1939	44	4,219,086	2	—	2	51	55	12,000	—	4,800	1,678	18,478	13.036	4.380
1940	46	4,358,409	1	—	5	78	84	6,000	—	2,550	3,013	11,563	19.273	2.653
1941	47	5,777,587	3	—	5	98	106	18,000	—	9,300	2,266	29,566	18.347	5.117
1942	48	7,178,935	3	2	1	183	189	18,000	12,000	1,500	4,239	35,739	26.327	4.978
1943	34	4,750,314	4	—	5	134	143	24,000	—	7,146	3,862	35,008	30.103	7.370
1944	32	3,996,433	3	—	4	118	125	18,000	—	3,000	3,323	24,323	31.278	6.086
1945	46	6,087,037	—	—	1	135	136	—	—	750	3,505	4,255	22.343	0.699
1946	46	7,292,175	1	—	6	197	204	6,000	—	5,141	4,130	15,271	27.975	2.094
1947	42	6,971,790	5	—	5	197	207	30,000	—	6,900	4,990	41,890	29.691	6.008
1948	47	6,953,569	4	—	11	181	196	24,000	—	8,018	4,642	36,660	28.187	5.272
1949	57	7,166,644	3	—	11	153	167	18,000	—	9,465	3,345	30,810	23.302	4.299
1950	45	6,510,173	2	—	7	153	162	12,000	—	3,854	3,825	19,679	24.884	3.023
1951	36	5,441,304	1	—	4	100	105	6,000	—	6,325	2,381	14,706	19.297	2.703
1952	36	5,279,849	3	—	3	111	117	18,000	—	1,674	2,296	21,970	22.160	4.161
Total	—	153,815,201	88	3	153	4,306	4,550	528,000	18,000	162,084	99,654	807,738	29.581	5.251

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

TABLE IV

YEARLY SUMMARY—UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1926–52 [1]

Year	Plants	Man-hours worked	Number of injuries [2]					Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
			F.	P. T.	P. P.	Temp.	Total	F.	P. T.	P. P.	Temp.	Total		
1926	3	517,926	—	—	—	34	34	—	—	—	533	533	65.646	1.029
1927	2	318,449	1	—	1	14	16	6,000	—	300	68	6,368	50.244	19.997
1928	5	542,193	1	—	1	68	70	6,000	—	300	888	7,188	129.105	13.257
1929	4	665,520	1	—	1	30	32	6,000	—	300	617	6,917	48.083	10.393
1930	6	595,367	1	—	1	15	17	6,000	—	225	468	6,693	28.554	11.242
1931	3	345,105	—	—	—	4	4	—	—	—	147	147	11.591	.426
1932	2	158,450	—	—	—	6	6	—	—	—	165	165	37.867	1.041
1933	3	229,381	—	—	—	11	11	—	—	—	349	349	47.955	1.521
1934	4	248,146	—	—	—	13	13	—	—	—	287	287	52.389	1.157
1935	2	175,994	—	—	—	3	3	—	—	—	249	249	17.046	1.415
1936	4	334,747	1	—	—	7	8	6,000	—	—	117	6,117	23.899	18.274
1937	3	364,680	—	—	—	3	3	—	—	—	91	91	8.226	.250
1938	3	334,442	—	—	—	2	2	—	—	—	133	133	5.980	.398
1939	4	393,039	—	—	1	7	8	—	—	600	457	1,057	20.354	2.689
1940	4	375,987	—	—	1	8	9	—	—	4,500	888	5,388	23.937	14.330
1941	4	591,568	—	—	1	15	16	—	—	750	169	919	27.047	1.553
1942	4	785,894	—	—	1	33	34	—	—	1,800	1,213	3,013	43.263	3.834
1943	5	1,019,771	—	—	3	45	48	—	—	4,950	1,123	6,073	47.069	5.955
1944	4	727,496	1	—	1	27	29	6,000	—	2,400	796	9,196	39.863	12.641
1945	7	1,238,845	—	—	2	22	24	—	—	3,000	755	3,755	19.373	3.031
1946	8	1,338,563	2	—	2	31	35	12,000	—	675	1,045	13,720	26.147	10.250
1947	8	1,291,162	5	—	1	29	35	30,000	—	75	1,588	31,663	27.107	24.523
1948	4	940,031	—	—	—	16	16	—	—	—	935	935	17.021	.995
1949	5	981,692	—	—	1	17	18	—	—	900	467	1,367	18.336	1.392
1950	6	1,102,273	1	—	1	25	27	6,000	—	3,000	810	9,810	24.495	8.900
1951	6	1,179,458	—	—	1	21	22	—	—	1,125	818	1,943	18.653	1.647
1952	6	1,137,449	—	—	—	19	19	—	—	—	583	583	16.704	.513
Total	—	17,933,628	14	—	20	525	559	84,000	—	24,900	15,759	124,659	31.170	6.951

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

TABLE V

YEARLY SUMMARY—QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1926-52 [1]

Year	Plants	Man-hours worked	Number of injuries [2]					Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
			F.	P. T.	P. P.	Temp.	Total	F.	P. T.	P. P.	Temp.	Total		
1926	43	5,816,909	3	—	6	241	250	18,000	—	9,000	4,772	31,772	42.978	5.462
1927	50	8,195,240	10	—	3	472	485	60,000	—	2,400	7,254	69,654	59.181	8.499
1928	58	8,051,291	9	—	5	390	404	54,000	—	9,000	6,381	69,381	50.178	8.617
1929	57	8,635,845	5	—	6	316	327	30,000	—	6,060	6,150	42,210	37.865	4.888
1930	74	8,608,782	7	—	10	242	259	42,000	—	7,475	4,139	53,614	30.086	6.228
1931	61	5,430,962	4	—	13	202	219	24,000	—	18,660	3,687	46,347	40.324	8.534
1932	42	2,820,300	1	—	4	81	86	6,000	—	6,750	2,646	15,396	30.493	5.459
1933	43	2,934,252	1	—	1	78	80	6,000	—	48	3,242	9,290	27.264	3.166
1934	50	3,536,403	1	—	2	119	122	6,000	—	2,850	2,160	11,010	34.498	3.113
1935	48	4,342,300	2	1	8	80	91	12,000	6,000	9,900	3,264	31,164	20.957	7.177
1936	54	6,733,770	6	—	14	189	209	36,000	—	8,168	4,707	48,875	31.038	7.258
1937	50	6,563,681	7	—	9	139	155	42,000	—	5,875	4,552	52,427	23.615	7.987
1938	50	4,992,561	2	—	6	78	86	12,000	—	6,600	3,317	21,917	17.226	4.390
1939	48	4,612,125	2	—	3	58	63	12,000	—	5,400	2,135	19,535	13.660	4.236
1940	50	4,734,396	1	—	6	86	93	6,000	—	7,050	3,901	16,951	19.643	3.580
1941	51	6,369,155	3	—	6	113	122	18,000	—	10,050	2,435	30,485	19.155	4.786
1942	52	7,964,829	3	2	2	216	223	18,000	12,000	3,300	5,452	38,752	27.998	4.865
1943	39	5,770,085	4	—	8	179	191	24,000	—	12,096	4,985	41,081	33.102	7.120
1944	36	4,723,929	4	—	5	145	154	24,000	—	5,400	4,119	33,519	32.600	7.096
1945	53	7,325,882	—	—	3	157	160	—	—	3,750	4,260	8,010	21.840	1.093
1946	54	8,630,738	3	—	8	228	239	18,000	—	5,816	5,175	28,991	27.692	3.359
1947	50	8,262,952	10	—	6	226	242	60,000	—	6,975	6,578	73,553	29.287	8.902
1948	51	7,893,600	4	—	11	197	212	24,000	—	8,018	5,577	37,595	26.857	4.763
1949	62	8,148,336	3	—	12	170	185	18,000	—	10,365	3,812	32,177	22.704	3.949
1950	51	7,612,446	3	—	8	178	189	18,000	—	6,854	4,635	29,489	24.828	3.874
1951	42	6,620,762	1	—	5	121	127	6,000	—	7,450	3,199	16,649	19.182	2.515
1952	42	6,417,298	3	—	3	130	136	18,000	—	1,674	2,879	22,553	21.193	3.514
Total	—	171,748,829	102	3	173	4,831	5,109	612,000	18,000	186,984	115,413	932,397	29.747	5.429

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

TABLE VI

NUMBER OF INJURIES, BY CLASSIFICATIONS, AT QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION IN 1952

Classifications	Fatal	Permanent		Tempo-rary	Total
		Total	Partial		
Falls and slides of rock or materials	1	—	—	15	16
Handling materials or objects	—	—	—	17	17
Hand tools	—	—	—	5	5
Explosives	—	—	—	—	—
Haulage	1	—	—	10	11
Falls of persons	1	—	—	18	19
Bumping against objects	—	—	—	4	4
Falling objects	—	—	—	14	14
Flying objects or particles	—	—	—	10	10
Electricity	—	—	—	4	4
Drilling	—	—	—	1	1
Machinery	—	—	3	7	10
Stepping on objects	—	—	—	6	6
Burns	—	—	—	2	2
Other causes	—	—	—	3	3
Total	3	—	3	116	122
Not stated	—	—	—	14	14
Grand total	3	—	3	130	136

TABLE VII

DAYS OF DISABILITY, BY CLASSIFICATIONS, OF INJURIES AT QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION IN 1952

Classifications	Fatal	Permanent		Tempo-rary	Total
		Total	Partial		
Falls and slides of rock or materials	6,000	—	—	688	6,688
Handling materials or objects	—	—	—	259	259
Hand tools	—	—	—	29	29
Explosives	—	—	—	—	—
Haulage	6,000	—	—	152	6,152
Falls of persons	6,000	—	—	384	6,384
Bumping against objects	—	—	—	122	122
Falling objects	—	—	—	281	281
Flying objects or particles	—	—	—	59	59
Electricity	—	—	—	17	17
Drilling	—	—	—	16	16
Machinery	—	—	1,674	229	1,903
Stepping on objects	—	—	—	204	204
Burns	—	—	—	65	65
Other causes	—	—	—	22	22
Total	18,000	—	1,674	2,527	22,201
Not stated	—	—	—	352	352
Grand total	18,000	—	1,674	2,879	22,553

TABLE VIII

NUMBER AND PERCENTAGE DISTRIBUTION OF INJURIES AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1950-52, BY CLASSIFICATIONS

Classifications	1950		1951		1952		Total	
	Number	Per cent of total	Number	Per cent of total	Number	Per cent of total	Number	Per cent of total
Falls and slides of rock	19	10.6	14	11.9	16	13.1	49	11.7
Handling materials	25	13.9	25	21.2	17	13.9	67	15.9
Hand tools	10	5.6	7	5.9	5	4.1	22	5.2
Explosives	1	.6	1	.9	—	—	2	.5
Haulage	23	12.8	5	4.2	11	9.0	39	9.3
Falls of persons	26	14.4	20	17.0	19	15.6	65	15.5
Bumping against objects	5	2.8	3	2.5	4	3.3	12	2.9
Falling objects	13	7.2	11	9.3	14	11.5	38	9.0
Flying objects	11	6.1	7	5.9	10	8.2	28	6.7
Electricity	8	4.4	—	—	4	3.3	12	2.9
Drilling	6	3.3	2	1.7	1	.8	9	2.1
Machinery	16	8.9	14	11.9	10	8.2	40	9.5
Stepping on objects	9	5.0	3	2.5	6	4.9	18	4.3
Burns	4	2.2	—	—	2	1.6	6	1.4
Other causes	4	2.2	6	5.1	3	2.5	13	3.1
Total	180	100.0	118	100.0	122	100.0	420	100.0
Causes not stated	9	—	9	—	14	—	32	—
Grand total	189	—	127	—	136	—	452	—

caused by falls or slides of rock, 12 per cent by falling objects, 9 per cent by haulage accidents, and flying objects and machinery accidents were equally responsible for 16 per cent of the total injuries. The most severe injuries during the 1952 competition resulted from falls or slides of rock, falls of persons, and from haulage and machinery accidents. These four agencies were responsible for 95 per cent of the total number of days of disability.

Summary of Tables

Tables I and II indicate the relative standing of open quarries and underground mines, arranged in descending order of injury-severity rates. When two or more plants show injury-free records, the number of man-hours establishes the order. Tables III, IV, and V contain yearly summary figures for the competing operations from 1926 through 1952. The number of injuries, days of disability, and percentage distribution by agencies involved are shown

TABLE IX

NUMBER OF AND PERCENTAGE DISTRIBUTION OF DAYS OF DISABILITY FROM INJURIES AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1950-52, BY CLASSIFICATIONS

Classifications	1950		1951		1952		Total	
	Days of disability	Per cent of total	Days of disability	Per cent of total	Days of disability	Per cent of total	Days of disability	Per cent of total
Falls and slides of rock	6,600	22.5	3,306	20.5	6,688	30.1	16,594	24.5
Handling materials	759	2.6	503	3.1	259	1.2	1,521	2.2
Hand tools	222	.8	60	.4	29	.1	311	.5
Explosives	17	.1	19	.1	—	—	36	.1
Haulage	3,762	12.8	1,215	7.5	6,152	27.7	11,129	16.4
Falls of persons	1,006	3.4	1,049	6.5	6,384	28.7	8,439	12.5
Bumping against objects	21	.1	86	.5	122	.5	229	.3
Falling objects	6,147	20.9	212	1.3	281	1.3	6,640	9.8
Flying objects	476	1.6	81	.5	59	.3	616	.9
Electricity	6,114	20.8	—	—	17	.1	6,131	9.1
Drilling	112	.4	52	.3	16	.1	180	.3
Machinery	3,903	13.3	3,449	21.4	1,903	8.6	9,255	13.7
Stepping on objects	32	.1	64	.4	204	.9	300	.4
Burns	34	.1	—	—	65	.3	99	.1
Other causes	156	.5	6,062	37.5	22	.1	6,240	9.2
Total	29,361	100.0	16,158	100.0	22,201	100.0	67,720	100.0
Causes not stated	128	—	491	—	352	—	971	—
Grand total	29,489	—	16,649	—	22,553	—	68,691	—

in Tables VI, VII, VIII, and IX. In Table X work-time and injury data for identical and non-identical operations enrolled in the 1952 and 1951 contest, are indicated. Table XI shows the average number of days of disability for temporary total injuries.

The Competition

This safety competition among operations in the crushed stone industry is conducted by the Bureau of Mines under the same rules as the National Safety Competition. The same records are used in both contests. However, there are two additional requirements that must be established before a crushed stone operation may participate in this competition, namely: (1) It must have commercial production of crushed stone, and (2) It must be a member of the National Crushed Stone Association.

TABLE X

EMPLOYMENT AND INJURY DATA FOR CRUSHED STONE PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1951 AND 1952, COVERING IDENTICAL PLANTS FOR BOTH YEARS AND PLANTS ENROLLED ONLY IN 1951 OR IN 1952 [1]

			Number of injuries [2]					Days of disability [2]						
	No.	Man-hours worked	F.	P. T.	P. P.	Temp.	Total	F.	P. T.	P. P.	Temp.	Total	Frequency rate [3]	Severity rate [3]
Plants enrolled in 1951 only	3	214,406	—	—	—	10	10	—	—	—	103	103	46.640	0.480
Identical plants enrolled both years, 1951	39	6,406,356	1	—	5	111	117	6,000	—	7,450	3,096	16,546	18.263	2.583
Identical plants enrolled both years, 1952	39	6,134,720	3	—	3	124	130	18,000	—	1,674	2,575	22,249	21.191	3.627
Plants enrolled in 1952 only	3	282,578	—	—	—	6	6	—	—	—	304	304	21.233	1.076

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates the number of days of disability lost from injuries per thousand man-hours of exposure

TABLE XI

AVERAGE DAYS OF DISABILITY PER TEMPORARY INJURY AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION

	Underground mines			Open quarries			Total		
Year	Number of temporary injuries	Number of days of disability	Average days of disability	Number of temporary injuries	Number of days of disability	Average days of disability	Number of temporary injuries	Number of days of disability	Average days of disabiliy
1926	34	533	16	207	4,239	20	241	4,772	20
1927	14	68	5	458	7,186	16	472	7,254	15
1928	68	888	13	322	5,493	17	390	6,381	16
1929	30	617	21	286	5,533	19	316	6,150	19
1930	15	468	31	227	3,671	16	242	4,139	17
1931	4	147	37	198	3,540	18	202	3,687	18
1932	6	165	28	75	2,481	33	81	2,646	33
1933	11	349	32	67	2,893	43	78	3,242	42
1934	13	287	22	106	1,873	18	119	2,160	18
1935	3	249	83	77	3,015	39	80	3,264	41
1936	7	117	17	182	4,590	25	189	4,707	25
1937	3	91	30	136	4,461	33	139	4,552	33
1938	2	133	67	76	3,184	42	78	3,317	43
1939	7	457	65	51	1,678	33	58	2,135	37
1940	8	888	111	78	3,013	39	86	3,901	45
1941	15	169	11	98	2,266	23	113	2,435	22
1942	33	1,213	37	183	4,239	23	216	5,452	25
1943	45	1,123	25	134	3,862	29	179	4,985	28
1944	27	796	29	118	3,323	28	145	4,119	28
1945	22	755	34	135	3,505	26	157	4,260	27
1946	31	1,045	34	197	4,130	21	228	5,175	23
1947	29	1,588	55	197	4,990	25	226	6,578	29
1948	16	935	58	181	4,642	26	197	5,577	28
1949	17	467	27	153	3,345	22	170	3,812	22
1950	25	810	32	153	3,825	25	178	4,635	26
1951	21	818	39	100	2,381	24	121	3,199	26
1952	19	583	31	111	2,296	21	130	2,879	22
Total	525	15,759	30	4,306	99,654	23	4,831	115,413	24

New Test Method for Direct Measurement of Maximum Density of Bituminous Mixtures

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> TO meet the present day requirements of heavy traffic, bituminous concrete paving mixtures must be carefully designed and closely controlled during construction. Paving mixtures must contain sufficient asphalt to insure durability but not so much as to impair stability. Regardless of how the proper asphalt content is determined, information about the void space in the compacted mixture is important since a lack of air voids may endanger stability.
>
> A prerequisite for the precise determination of void content is a knowledge of the voidless or maximum density of the paving mixture. The normal procedure for determining this value is time consuming and the results are often inapplicable. The test described herein provides a rapid and accurate method for the direct measurement of the maximum density of bituminous mixtures.

FOR the past several years the laboratory of the National Crushed Stone Association has been investigating methods for the direct measurement of the percentage voids and maximum specific gravity of bituminous mixtures. The method that has been developed consists of evacuating the entrapped air from a sample of *uncompacted* mixture and then determining the volume and specific gravity of the voidless mixture by water displacement. The percentage voids of *compacted samples from the same mixture* can then be computed from the difference between the specific gravities of the compacted and uncompacted mixtures. The publication of detailed accounts of these investigations[1] has generated interest in establishing a standard test method. The purpose of this article is to present the test method and to describe its advantages, limitations and applications.

Importance of Voids

The percentage voids is one of the tools by which the paving engineer judges the design and compaction of bituminous concrete mixtures. Many specifications require that mixtures shall have, say, "2 to 6 per cent voids," or shall be compacted to "94 to 98 per cent of theoretical maximum density."

It is important that a bituminous pavement have some void space in order to accommodate densification due to traffic and to provide space for the expansion of the bituminous material during hot weather. Otherwise, the pavement may lack stability when warm and become slippery when wet.

An excessive amount of voids permits the ready access of air and water, which may lead to failure of the mixture by hardening or stripping of the binder or by softening of the base due to excess moisture.

Many factors influence the void content of a compacted mixture. Some of these, such as asphalt content and gradation of aggregates are design factors; while others are controlled in construction, i.e., temperature, pressure, and number of passes of roller. In still another category is the method used for computing the void content.

Theoretical Methods

In the past, it has been customary to determine the void content by first calculating the "theoretical maximum specific gravity" for the mixture without any air voids. This theoretical value is then compared with the bulk specific gravity of a compacted sample and the difference in values is a measure of the void content.

The "theoretical maximum specific gravity" is an average of the specific gravities of the constituents

[1] "The Measurement of Voids in Bituminous Mixtures by Pressure Methods," and "Volumetric Methods for Measuring Asphalt Content and Effective Gravity of Aggregates in Bituminous Mixtures," *Proceedings*, The Association of Asphalt Paving Technologists, 1952, 1953

weighted on the basis of their proportions by volume. An example of this method follows:

Constituent Material	Specific Gravity	Proportions by Volume	Weighted Specific Gravity	Proportions by Weight
Coarse aggregate	2.95	40	1.18	47.2
Fine aggregate	2.60	45	1.17	46.8
Asphalt cement	1.00	15	.15	6.0
Theoretical maximum sp gr, D =			2.50	

Actually, since most mixtures are proportioned on a weight basis, the theoretical maximum specific gravity (D) would be obtained as follows:

$$D = \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_s}{S}} \qquad (1)$$

where W_1, W_2, and W_s are percentages by weight of aggregates and asphalt, and G_1, G_2, and S are specific gravities of aggregates and asphalt.

Example:

$$D = \frac{100}{\frac{47.2}{2.95} + \frac{46.8}{2.60} + \frac{6.0}{1.00}} = 2.50$$

The bulk specific gravity of a *compacted* sample may be determined from measurements of weight and dimensions, or by the water displacement method.[1] In the latter method, the sample is weighed in water and in air, and the bulk specific gravity (d) is determined as follows:

$$d = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}} \qquad (2)$$

The percentage voids (V_m) in the compacted sample is then calculated as follows:

$$V_m = \frac{D - d}{D} \times 100 \qquad (3)$$

For example, if the bulk specific gravity of the compacted mixture equals 2.36

$$V_m = \frac{2.50 - 2.36}{2.50} \times 100 = 5.6$$

[1] "Tentative Method of Test for Specific Gravity of Compressed Bituminous Mixtures" (ASTM Designation: D 1188-51T)

Disadvantages of Theoretical Method

There are several sources of error in the above method. If, due to the vagaries of plant control, the proportions of fine and coarse aggregate should be changed by as little as 5 per cent, the calculated voids could be in error by about 0.5 per cent. Likewise, a change in asphalt content of 0.3 per cent, would also affect the calculated voids by 0.5 per cent. Such errors would be important in borderline cases.

Another disadvantage of the theoretical method is the time necessary to measure the specific gravities of the materials. Standard specific gravity tests require three days time. The direct measurement by vacuum saturation requires only 30 min and can be applied to mixtures about which no information is available as to proportions or constituents.

An even more troublesome point is the question of what specific gravity value should be assigned to the aggregates for calculating the theoretical maximum specific gravity. Standard tests have long been in use for determining the "bulk" and "apparent" specific gravities of aggregates. The specific gravity of a substance is the ratio of its weight to the weight of an equal volume of water. But what is the "volume" of a porous aggregate? The bulk volume, which determines the bulk gravity, is the total volume occupied by the aggregate *including permeable pore space.* The apparent gravity is based on the apparent volume of the aggregate which does not include those pores that are permeable to water. The apparent gravity is always higher than the bulk gravity since the apparent volume is less than the bulk volume. A third term, "bulk-saturated-surface-dry", is sometimes used in concrete technology. This value is about 1/3 the way from the bulk value to the apparent.

If the bulk gravity is used for calculating the theoretical maximum specific gravity, it is assumed that the aggregate absorbs no asphalt into its pores. The use of the apparent gravity involves the assumption that the aggregate absorbs as much asphalt as it does water when soaked 24 hours. Should the bulk-saturated-surface-dry value be used, it would be assumed that the asphalt absorption is about 1/3 the water absorption. In certain cases any one of these three gravity values might be correct. However, considering the differences in

Illustrations of How Absorption May Affect the Calculated Voids

The diagrams below, which are based on concepts presented by Martin and Layman,[1] represent the absorption conditions that theoretically might exist in a compacted bituminous mixture, and show how the absorption may affect the voids in the mixture. Each of the samples illustrated has the same total volume (represented by the square area), the same asphalt content (**V_s**, shown in black), and the same amount of aggregate (**V_b**, large circle). The segments of the circles represent the total capillary pore space (**V_p**) of the aggregate which may be more or less filled with asphalt. The small circles (**V_m**) represent the air voids in the compacted mixture.

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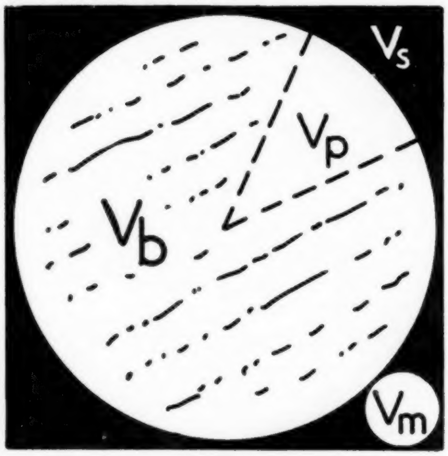
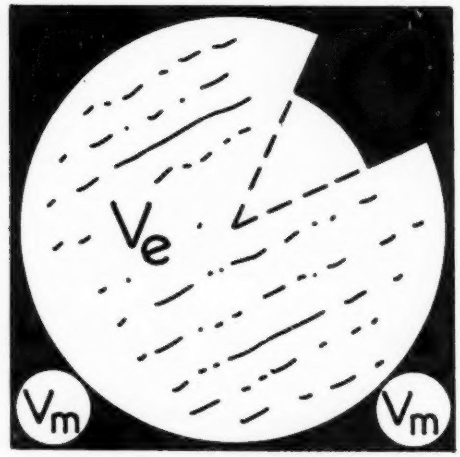
[1] Martin, J. R., and Layman, A. H., "Hot-Mix Asphalt Design Studies," Oklahoma A. &. M. Engineering Experiment Station Publication No. 75, 1950



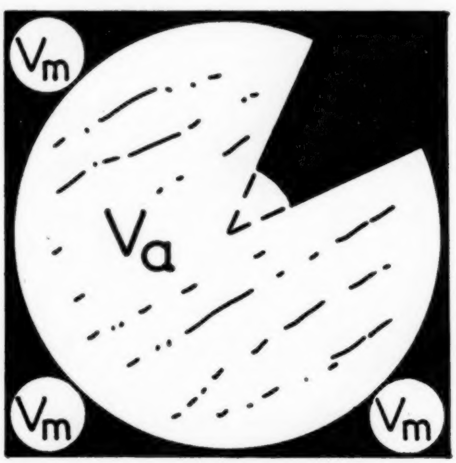
CASE 1

Case 1 illustrates a condition of no absorption corresponding to the use of the bulk specific gravity of the aggregate for calculating the theoretical maximum specific gravity. Note that this example has the least air voids (**V_m**) in the mixture.



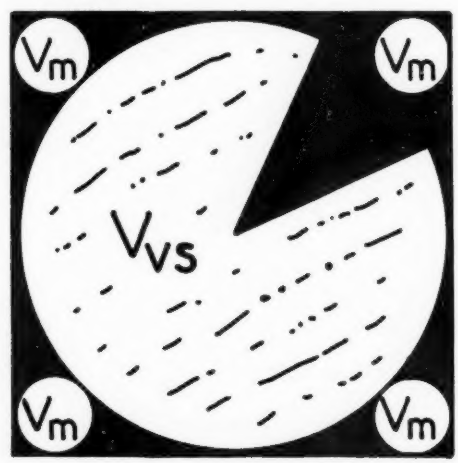
CASE 2

Case 2 represents the actual conditions that normally exist in bituminous mixtures. A portion of the asphalt is absorbed into the pores of the aggregate; therefore, the voids are greater than in Case 1. **V_e** represents the effective solid volume of the aggregate.



CASE 3

Case 3 illustrates the conditions when the asphalt absorption is assumed to be identical to the 24-hour water absorption which determines the ASTM apparent specific gravity. **V_a** represents the apparent volume of the aggregate corresponding to 24-hour water immersion.



CASE 4

Case 4 shows complete saturation of the pores. This condition would rarely be found in bituminous mixtures, but may occur in nature with river-wet gravel or quarry-wet stone. **V_{vs}** represents the apparent volume as ascertained by vacuum-saturation of uncoated aggregate.

FIGURE 1

surface tension and viscosity of water and asphalt and the time during which the asphalt is hot and fluid, these instances are purely coincidental.

Aggregates do absorb some asphalt and this factor should not be overlooked even with aggregates having relatively low absorption—less than 1 per cent. Absorption values are normally given on a weight basis, whereas the *volume* of the absorbed asphalt is the important factor. For an aggregate with only 1 per cent absorption by weight, the calculated percentage voids could vary by more than 2 per cent, depending upon the gravity value used. A feature of the direct measurement method is that it automatically compensates for the absorption of asphalt that occurs under the actual mixing conditions.

Figure 1 illustrates how the calculated voids may be affected by absorption.

METHOD OF TEST FOR SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES

Scope

1. This method of test is intended for determining the maximum or voidless specific gravity of bituminous paving mixtures using uncompacted samples.

Apparatus

2. The apparatus shall consist of the following:

(a) Balance—A balance sensitive to 0.05 per cent of the weight of the sample to be weighed.

(b) Container—The container may be either a glass flask or a glass or metal bowl. (The bottom section of a 1 1/2 quart capacity, Pyrex glass, double boiler unit makes a satisfactory container.) Containers should be sufficiently strong to withstand partial vacuum. In order to use the flask as a volumetric container the top surface shall be smooth and substantially plane. The size of the container will be governed by the maximum size of the aggregate in the mixture according to the following requirements:

Size of Largest Particle of Aggregate in Mixture, in.	Capacity, ml	Sample Size, g
1	4000	2500
3/4	3000	2000
1/2	2000	1500
3/8	1500	1000
No. 4	750	500

(c) For use with the bowl, a container suitable for immersing the bowl in water and suitable apparatus for suspending the bowl from center of scale pan of balance.

Calibration of Flask

3. The flask shall be calibrated by accurately determining its weight when filled with water at 25 C (77 F). Designate this weight as "D". Accurate filling of the flask may be secured by the use of a glass cover plate.

Test Samples

4. *(a)* The sample shall be obtained in accordance with the Standard Methods of Sampling Bituminous Paving Mixtures (ASTM Designation: D 979-51).

(b) The size of the sample shall conform to requirements of Section 2*(b)*. Large samples may be tested a portion at a time.

Procedure

5. *(a)* The sample shall be separated, using care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 1/4 in. If the mixture is not sufficiently soft to be separated manually, it shall be placed in a large flat pan and warmed in the oven only until it can be so handled.

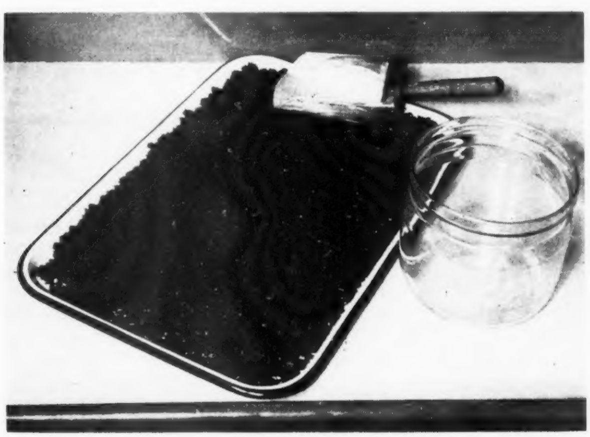


FIGURE 2
Uncompacted Mixture Prepared for Testing

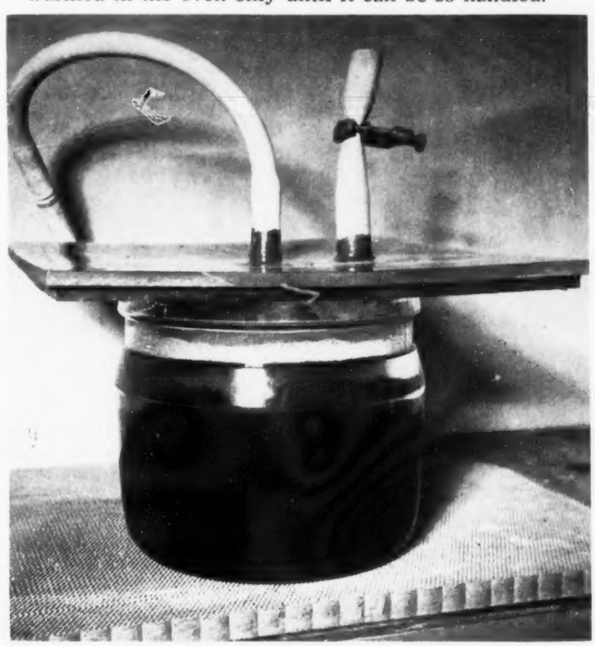


FIGURE 3
Evacuating Entrapped Air from Mixture

(b) The sample shall be cooled to room temperature and shall be placed in the flask or bowl and weighed. Designate the net weight of the sample as "A". Water at approximately 25 C (77 F) shall be added to cover the sample.

NOTE—A suitable wetting agent added to the water will facilitate the release of entrapped air.

(c) Entrapped air shall be removed by subjecting the contents to a partial vacuum (air pressure less than 2 cm of mercury) for approximately 10 min. Subjection of contents to reduced air pressure may be done by connecting the flask or bowl directly to an aspirator or vacuum pump, or by use of a bell jar.

(d) Bowl Determination—The bowl and contents shall be suspended in water at 25 C (77 F) and weighed after approximately 10 min immersion. Designate the net weight of the sample in water as "C".

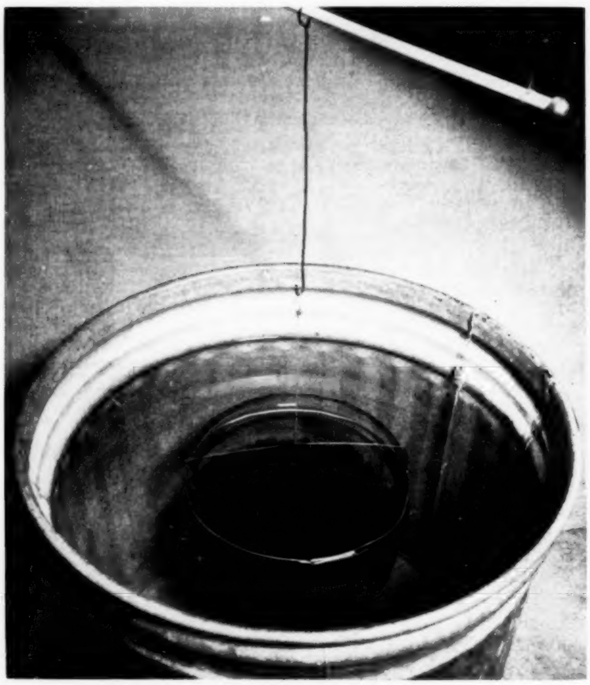


FIGURE 4
Weighing Bowl and Mixture in Water

(e) Flask Determination—The flask shall then be filled with water and the contents brought to a temperature of 25 C (77 F). The weight of the flask and contents shall then be determined. Designate this weight as "E".

(f) In case the specimen contains moisture, it is necessary to correct weight "A" for weight of moisture. After determining weight "C" or "E", determine the percentage moisture by weight in the original sample in accordance with the Standard Method of Test for Water in Petroleum Products and of Bituminous Materials (ASTM Designation: D 95) and apply appropriate correction to weight "A".

FIGURE 5
Alternate Method Using Calibrated Flask

Calculation

6. Calculate the specific gravity of the test samples as follows:

(a) Bowl Determination:

$$\text{Specific gravity} = \frac{A}{A - C}$$

where:

A = weight in grams of dry sample in air
C = weight in grams of sample in water

(b) Flask Determination:

$$\text{Specific gravity} = \frac{A}{A + D - E}$$

where:

D = weight in grams of flask filled with water at 25 C (77 F)

E = weight in grams of flask filled with water and sample at 25 C (77 F)

Reproducibility

7. The specific gravity obtained in duplicate tests on portions of the same sample should not vary by more than 0.01.

Limitations of Test Method

Before discussing the actual application of the direct measurement method, it may be well to point out certain limitations. For accurate results, the aggregate must be thoroughly coated with bitu-

minous material, otherwise water may penetrate into the pores of the aggregate. If the aggregate is known to be absorptive and the large particles appear dull rather than glossy, it may be anticipated that some water may be absorbed during the specific gravity test. An estimate of the amount of water absorbed by the aggregate can be ascertained from the weight of mixture after the surface moisture has been removed by drying before a fan. However, this expedient has not yet been proven to be sufficiently accurate for more than approximate results.

On the other hand, with sheet asphalt mixtures containing large amounts of filler and hard asphalt, the normal procedure may not remove all of the air entrapped in the matrix of the mixture. By breaking up the mixture as thoroughly as possible and by extending the time of evacuation, this difficulty should be minimized.

At present, the test method has been applied only to mixtures containing penetration grade asphalts. The test may be equally applicable for mixtures made with liquid asphalts or it may be necessary to operate the evacuation at a higher pressure for a shorter period of time.

Example of Test Calculations

The foregoing description of the test method is believed to be adequate, but an example of the actual calculations involved may be helpful.

Before Vacuum Saturation	
Weight of bowl plus mixture in air	1587.7 g
Weight of bowl in air	587.7 g
Weight of mixture in air, A	1000.0 g
After Vacuum Saturation	
Weight of bowl plus mixture in water	1000.8 g
Weight of bowl in water	400.8 g
Weight of mixture in water, C	600.0 g
Calculation	
Weight of water displaced by mixture, A − C	400.0 g
Specific gravity of mixture, $D_m = \frac{A}{A-C}$	2.500

This specific gravity value ($D_m = 2.500$) may then be used to calculate the percentage voids by substituting D_m for D in equation (3). The value can also be utilized to obtain additional information.

Other Applications

EFFECTIVE GRAVITY OF AGGREGATES

The *effective solid volume* of the aggregate is that volume occupied by the aggregate not including absorbed asphalt. (See Case 2, Fig. 1) If the specific gravity and amount of asphalt are known, the effective gravity of the aggregate can be determined from the weight and volume of the mixture directly, as follows:

Weight of uncompacted mixture		1000.0 g
Weight of asphalt	$= 0.06 \times 1000.0$	60.0 g
Weight of aggregate	$= 1000.0 - 60.0$	940.0 g
Volume of uncompacted mixture		400.0[1]
Volume of asphalt	$= 60.0 \div 1.00$	60.0[1]
Volume of aggregate	$= 400.0 - 60.0$	340.0[1]
Effective gravity of aggregate,	$G_e = 940.0 \div 340.0$	2.765

The effective gravity of the aggregate may also be calculated from equation (1) in the following form:

$$G_e = \frac{100 - W_s}{\frac{100}{D_m} - \frac{W_s}{S}} \qquad (4)$$

where

G_e = effective gravity of aggregate
W_s = percentage asphalt (by weight of mixture)
D_m = specific gravity of uncompacted mixture
S = specific gravity of asphalt

Example:

$$G_e = \frac{100 - 6.0}{\frac{100}{2.500} - \frac{6.0}{1.00}} = 2.765$$

ASPHALT ABSORPTION

Knowing the effective gravity of the aggregate it is possible to compute the amount of asphalt absorbed by the aggregate if the bulk gravity of the combined aggregate is known.

$$A = \frac{G_e - G_b}{G_e \times G_b} \times S \times 100 \qquad (5)$$

where

A = percentage absorbed asphalt (by weight of aggregate)
G_e = effective gravity of aggregate
G_b = bulk gravity of aggregate
S = specific gravity of asphalt

Assuming the individual G_b values for the coarse and fine aggregates in original example to be 2.90 and 2.50, respectively,

$$G_b = \frac{94}{\frac{47.2}{2.90} + \frac{46.8}{2.50}} = 2.686$$

Example:

$$A = \frac{2.765 - 2.686}{2.765 \times 2.686} \times 1.00 \times 100 = 1.06$$

[1] These "volumes" are actually the weights of equivalent volumes of water at 77 F

The test results tabulated in Table I illustrate the range in specific gravity values and the difference in asphalt and water absorption for several coarse aggregates.

EFFECTIVE ASPHALT CONTENT

The asphalt that is absorbed into the pores of the aggregate serves no purpose except to waterproof the interior of the aggregate. This absorbed asphalt must be deducted from the total asphalt content in order to ascertain the amount of asphalt that is effective as void filler and binder. This can be done as follows:

$$W_x = W_s - \frac{W_a \times A}{100} \qquad (6)$$

where

W_x = effective percentage asphalt (by weight)
W_s = total percentage asphalt
W_a = percentage aggregate (by weight)
A = percentage absorbed asphalt

Example:

$$W_x = 6.0 - \frac{94 \times 1.06}{100} = 5.0$$

The *volumetric* percentage of asphalt that is effective as void filler and binder may be obtained from the formula:

$$V_x = \frac{W_x \times d}{S} \qquad (7)$$

where

V_x = effective percentage asphalt (by volume)
d = bulk gravity of compacted mixture
S = specific gravity of asphalt

Example:

$$V_x = \frac{5.0 \times 2.36}{1.00} = 11.8$$

Note: d = 2.36 from equation (2)

VOIDS IN AGGREGATE AND VOIDS FILLED

In the design of bituminous mixtures, it is sometimes desirable to compute the percentage voids in the compacted aggregate and also the extent to which these voids are filled by asphalt. The volume of the voids in the compacted aggregate equals the sum of the voids in the mixture plus the *effective volume* of asphalt, that is,

$$VMA = V_m + V_x \qquad (8)$$

where

VMA = percentage voids in compacted aggregate
V_m = percentage voids in compacted mixture
V_x = effective percentage asphalt (by volume)

Example:

$$VMA = 5.6 + 11.8 = 17.4$$

Note: V_m = 5.6 from equation (3)

This value could also be computed from the bulk gravities of the aggregate and the compacted mixture as follows:

$$VMA = 100 - \frac{W_a \times d}{G_b} \qquad (9)$$

where

W_a = percentage aggregate (by weight)
d = bulk gravity of compacted mixture
G_b = bulk gravity of aggregate

Example:

$$VMA = 100 - \frac{94 \times 2.36}{2.686} = 17.4$$

TABLE I

RESULTS OF SPECIFIC GRAVITY AND ABSORPTION TESTS ON TEN COARSE AGGREGATES
(Listed in order of increasing asphalt absorption)

Sample No.	Type of Aggregate	Specific Gravity, 77/77 F: Bulk Dry, G_b	Effective[1], G_e	Apparent by 24 Hour Immerson	Apparent by Vacuum Saturation	Absorption, Per Cent by Volume[2]: Asphalt Cement[3]	Water by 24 Hour Immerson	Water by Vacuum Saturation	Ratio of Asphalt Absorption to 24 Hour Water Absorption
4001	Gravel	2.564	2.590	2.649	2.674	1.00	3.21	4.11	0.31
4578	Limestone	2.613	2.656	2.709	2.710	1.62	3.54	3.58	0.46
4573	Limestone	2.675	2.725	2.748	2.749	1.83	2.65	2.69	0.69
4384	Dolomite	2.676	2.735	2.818	2.833	2.16	5.04	5.54	0.43
4376	Dolomite	2.695	2.771	2.805	2.830	2.74	3.92	4.77	0.70
4650	Trap	2.853	2.935	2.971	2.976	2.79	3.97	4.13	0.70
4589	Limestone	2.677	2.763	2.820	2.847	3.11	5.07	5.97	0.61
4272	Limestone	2.619	2.725	2.813	2.848	3.89	6.90	8.04	0.57
4635	Limerock	2.333	2.466	2.533	2.703	5.39	7.90	13.69	0.68
4634	Sandstone	2.329	2.523	2.659	2.713	7.69	12.41	14.15	0.62

[1] Test sample composed of equal parts of ⅜ in. aggregate and non-absorptive quartz sand
[2] The percentage by *weight* = percentage by volume times S/G_b
[3] Specific gravity of asphalt, S = 1.014; penetration = 85

The percentage of the voids in the aggregate filled by asphalt is based on the ratio of the *effective volume* of asphalt to the voids in aggregate, that is

$$V_f = \frac{V_x}{VMA} \times 100 \qquad (10)$$

where

V_f = percentage of aggregate voids filled by asphalt

Example:

$$V_f = \frac{11.8}{17.4} \times 100 = 67.8$$

MEASURING ASPHALT CONTENT

Still another application is the determination of asphalt content. If from previous laboratory tests, the effective gravity of an aggregate has been established for a given set of conditions (asphalt, mixing time, and temperature), the asphalt content (total) for a similar mix may be computed by using the formula:

$$W_s = \frac{G_e - D_m}{G_e - S} \times \frac{S}{D_m} \times 100 \qquad (11)$$

where

W_s = percentage asphalt (by weight of mixture)
G_e = effective gravity of aggregate
D_m = specific gravity of uncompacted mixture
S = specific gravity of asphalt

For example, if the specific gravity of the uncompacted mixture (D_m) was found to be 2.480, the asphalt content would be

$$W_s = \frac{2.765 - 2.480}{2.765 - 1.00} \times \frac{1.00}{2.480} \times 100 = 6.5$$

Summary

The vacuum-saturation technique for the direct measurement of the maximum specific gravity of bituminous mixtures is believed to be a realistic solution to problems that have long confronted asphalt paving technologists. The test has certain limitations as to types of mixtures that may be used, but further research may eliminate these restrictions. With proper samples, the method is rapid, accurate, and requires no equipment that is not usually available at testing laboratories or that cannot be easily obtained. The method also eliminates the need for time consuming specific gravity tests on constituents which are really not applicable, and should facilitate the study of mixtures where accurate information as to constituent materials is lacking. The test is now being used for the practical control of bituminous mixtures and it is anticipated that its use will be extended.

Joseph A. Holmes Safety Award Presented to John Kawaske

ON July 17, 1953, members of the Eastern New York Mineral Aggregates Safety Council inspected the quarry crushing plant and agricultural limestone plant of the Callanan Road Improvement Company at South Bethlehem, New York.

During the visitation John Kawaske, General Superintendent of the Company, was presented a Type B Joseph A. Holmes Safety Association Award on behalf of John J. Forbes, President of the Association and Director of the Bureau of Mines, by Royden M. Loucks of the Albany Section of the Bureau.

PRESENTATION OF AWARD
MR. KAWASKE (left) and MR. LOUCKS

This award was presented to Mr. Kawaske for supervising the South Bethlehem and Kingston Quarries of the Company for a total of 615,812 man-hours without a lost-time accident. This was the largest run of no lost time the Company has ever enjoyed. The Kingston plant operated 718 consecutive days without a lost-time accident and the South Bethlehem plant 650 days.

Mr. Loucks, in presenting the award, mentioned

(Continued on Page 20)

Macadam Bases[1]

By FRED E. SWINEFORD
Engineer-Director
Macadam Pavements, Inc.
Columbus, Ohio

THE need for adequate bases for pavements is recognized more today than ever before. Base courses are now required under every type of pavement. Years of experience with all types of pavements has shown that pavements laid on plastic or unstable soils will not stand up under the heavy loads of today. Flexible pavements must have thick bases to distribute the wheel loads over a large area of the subgrade. Rigid pavements require stable, non-plastic bases to prevent pumping and breaking of the slabs. Adequate surface and subsurface drainage is essential for all types of bases.

Macadam Bases

Macadam bases may be designed of sufficient thickness to distribute the expected wheel loads over a sufficiently large area of the subgrade so that the bearing capacity of the subgrade will not be exceeded.

The downward pressure of the wheel load is transmitted by the base to the subgrade through a 45 degree cone and distributed over an area of the subgrade equal to the square of the depth of the base multiplied by 3.1416. Editor's Note: See the Crushed Stone Journal, June 1948, for a discussion of "The Problem of Flexible Pavement Design."

The types of macadam bases and the uses of each are as follows:

Waterbound macadam may be used for the first or second base course. It consists of large sized angular crushed rock (stone or slag) compacted and filled with finely crushed rock, then saturated with water. Dry bound macadam is built like waterbound macadam except the watering is omitted. Under either of these courses it is best to spread one or two inches of stone screenings as insulation against the intrusion of clay or mud coming up between the big stones. Such intrusion of clay would lubricate the rock and permit them to move, whereas, angular crushed rock and screenings interlock, one particle with another, and thus high internal friction is imparted to the mass which prevents any one particle from rotating with respect to its neighbor.

Waterbound or dry bound macadam formerly laid in courses four to six inches thick is now being laid eight to ten inches thick with the aid of vibration. The crushed rock for these thick courses is spread through a self-propelled mechanical spreader, then the lower part of the course is compacted by a heavy vibrator and the upper part compacted by a heavy roller.

Filling the voids with finely crushed rock is also accomplished with vibration and rolling combined. After the course is compacted to refusal one half of the stone screenings required to fill the course is spread. These are jarred into the lower half of the course by a heavy self propelled vibrator. Then one fourth of the filler screenings is applied and vibrated into the voids, then the last one fourth is applied, vibrated and rolled.

These thick courses of macadam are stronger and cost less than the same total thickness constructed in two thin courses.

Eight inch, one course macadam bases were laid for heavy duty airport runways at Binghamton, New York; Beaver Falls, Pa.; Chattanooga and Nashville, Tenn.; Beckley, W. Va.; and Columbus, Ohio, also on a number of highway pavements. As a result of the success of thick macadam courses for heavy duty roads and runways the ten mile test road at Columbus, Indiana will include an eight inch, one course, waterbound macadam base course of crushed stone macadam.

Specifications for macadam courses up to ten inches thick have been adopted by the Civil Aeronautics Administration, the U. S. Navy and the States of Ohio, Virginia, and North Carolina, also on certain projects by the U. S. Army and the States of Pennsylvania, New Jersey and Indiana. All of these specify that both vibration and rolling shall be used on thick courses. Macadam courses up to five inches thick are best laid by rolling only and from five to ten inches by vibration and rolling combined.

Bituminous Macadam

Bituminous penetration macadam courses consisting of compacted, crushed rock cemented together with a bituminous binder filled with smaller keystone are used for intermediate base courses.

[1] Prepared for "Construction of Road Bases" Panel, Ohio Highway Engineering Conference, May 20, 1953

Hundreds of thousands of miles of bituminous penetration macadam built throughout the United States have satisfactorily carried traffic during the past thirty years.

The 118 mile New Jersey Turnpike has eight inches of penetration macadam for its principal base course. Likewise the four lane National Pike now under construction south of Frederick, Maryland has a three inch bituminous penetration course laid over eight inches of waterbound macadam. Four inches of asphaltic concrete is then laid over the bituminous macadam. There are thousands of miles of existing highways which are now too narrow and weak to carry present day traffic. These can be widened and strengthened to carry the traffic for many years.

The new super highways and expressways cannot be built quickly enough to take care of traffic for the next ten or twenty years. Consequently, we must maintain, strengthen, widen and correct our existing highways to carry the traffic while the new super highways are being built. The investment in maintenance and betterments of the old roads will not be lost because they will continue to serve local traffic and to a certain extent classify traffic. The slower local traffic will use the old roads and the faster through traffic will use the new super highways. Bituminous macadam strengthening courses are well adapted to modernize these old pavements.

Bituminous penetration macadam has so much stability and toughness that it is being used not only for surface courses and intermediate base courses but for a strengthening and insulation course over broken rigid slabs which need resurfacing. Over the past five years this has been so successful in New York State that in 1952 they resurfaced 34 miles of State Route 5 west of Buffalo with four inches of penetration macadam topped with two and one half inches of dense asphaltic concrete.

They found that when they resurfaced broken and pumping rigid slabs with hot mixed asphaltic concrete only the cracks came up through and pumping continued, but by first placing a four inch course of penetration macadam over the broken slab prior to laying the hot mix pumping ceased and few cracks came through.

Other Types of Macadam Bases

Another modification of macadam is a base of crushed rock or slag including medium size down and including the fine screenings. This is spread, bladed and rolled at the proper moisture content. It was used as a sub-base on the New Jersey Turnpike and the Oklahoma Turnpike.

Other types of bituminous macadam bases for courses thinner than ordinarily specified for penetration macadam are those known as bituminous premixed base and leveling courses. These are composed of smaller aggregate than that used in penetration macadam and are mixed with bituminous binder in a stationary or travelling plant or mixed on the road.

Such mixtures are spread with a mechanical spreader and are especially well adapted to leveling up old, rough pavements.

Quality Control and Construction Methods

Riding quality, stability, and durability of pavements depend on good construction methods and adequate control from the subgrade to the surface. The load carrying capacity of the macadam bases on the New Jersey Turnpike were tested with 50 ton super compactors and all defective areas were repaired. The finished surface was tested and conformed to the requirement of 1/8 in. variation in 16 ft.

Variations in the subgrade will show up in the finished surface. The subgrade must be checked by lines and templets to make sure it conforms to cross section and profile. The base courses will not correct ups and downs in the subgrade. Soft areas in the subgrade will result in low spots in the finished surface. Finished grade stakes should be set every 25 ft. on both sides of the pavement. From these the subgrade and every succeeding course must be checked and corrected if necessary. From the grade stakes the contractor should set iron pins along both sides and on the center line. Longitudinal chalk lines between these iron pins provide line and profile for the guides on the mechanical spreaders and pavers. These lines also provide a guide for the transverse screed and templet.

For quick check use the roller eye method. Stand behind a roller moving over the course. Fix your line of sight over the top of the big roll on a distant object like a telephone cross arm. The ups and downs of the roll from your line of sight will magnify the variations in the course so you can soon see if it is wavy.

The rock for the macadam base and surface course should be spread to a uniform thickness true to crown and profile. Compaction of these courses should continue until the roller wheels or truck tires do not disturb the stone.

Waterbound or dry bound macadam bases should be filled with several applications of screenings. The applications of screenings must be light enough so that they will not crust on the top but go down and fill the voids from the bottom up.

With vibration and rolling combined three applications of screenings will fill an eight inch course. With rolling only, no more than a six inch course can be filled and the number of applications of screenings should equal the number of inches in depth of the course. Filling the voids should follow closely behind the coarse stone so as not to leave the course open and permit rain to go through and soften the subgrade. Waterbinding should continue until the stone is thoroughly wetted to the bottom of the course. Any pools of water standing on the course show where there are low areas which should be corrected.

A prime coat of light bituminous material is desirable on waterbound or dry bound macadam bases which are to be covered with asphaltic concrete. Prime coats are not necessary where a bituminous penetration macadam course is laid on such bases. Bituminous macadam base courses need no seal coat but a good seal is necessary when they are used on surface courses.—Reprinted from *The Ohio County Engineers News,* July 1953.

Joseph A. Holmes Safety Award

(*Continued from Page 17*)

the background and history of the Joseph A. Holmes Safety Association. Dr. Holmes was the first director of the Bureau of Mines. The Association was organized in 1916 by 24 leading national organizations to commemorate Dr. Holmes' efforts to reduce accidents in the mining, metallurgical, and allied fie'ds by making awards for life saving, outstanding safety records of individuals, and outstanding safety records of mines and quarries.

Mr. Kawaske, in accepting the award, paid tribute to the workers at both plants for the cooperation they gave during that period. He said that without the aid of each employee, the record made would not have been possible, and since they made the greatest contribution the award belongs to them as much as to him.

At the luncheon for the Safety Council following the ceremony, J. Reid Callanan, President of the Company, in paying tribute to Mr. Kawaske, mentioned that in the 34 years with the Company, Mr. Kawaske had never suffered a lost-time accident himself.

F. H. Jackson Retires from the Bureau of Public Roads

THE retirement of Frank H. Jackson from the U. S. Bureau of Public Roads on September 30 should not go unnoticed by the crushed stone industry, for Mr. Jackson, through his work with the Bureau of Public Roads, has helped to provide our industry with much basic information.

In 1905 Frank Jackson became a laboratory apprentice with Public Roads and during his 48 years of service he rose to the position of Chief of the Non-Bituminous Section of the Physical Research Branch and has achieved an international reputation as an authority on aggregates and concrete.

He is a member of many technical societies, has served as President of the American Concrete Institute, a member of many of its technical committees and is the author of numerous technical papers. He is an Honorary Member of the American Society for Testing Materials, granted for long and distinguished service, and a past Secretary of the Committee on Materials of the American Association of State Highway Officials. Likewise, he has been very prominent in the affairs of the Highway Research Board and other organizations.

Although Mr. Jackson has retired from service with the Bureau of Public Roads, he intends to continue his technical activities in his chosen field. We wish him continuing success.

ARBA Directory of Highway Officials and Engineers

THE American Road Builders' Association has issued in convenient pocket size its 1953 edition of "Highway Officials and Engineers." This publication should be of very real interest and value to all interested in the highway field.

In addition to listing administrative personnel of the 48 state highway departments, the District of Columbia, and the Bureau of Public Roads, the 1953 Directory contains a listing of the personnel of toll road authorities now organized and functioning in the various states. It also contains a listing of the officers and directors of ARBA and its organized divisions. Tabulations by states are included which show funds expended during the past year, as well as an estimate of expenditures for the current year.

Copies of this Directory are available at $1.00 per copy and requests should be made direct to the ARBA, World Center Building, Washington 6, D. C.

Manufacturers Division—National Crushed Stone Association

These associate members are morally and financially aiding the Association in its efforts to protect and advance the interests of the crushed stone industry. Please give them favorable consideration whenever possible.

Allis-Chalmers Mfg. Co.
Milwaukee 1, Wis.
Crushing, Screening, Washing, Grinding, Cement Machinery; Motors; Texrope Drives; Centrifugal Pumps; Tractors

American Cyanamid Co.
Explosives Department
30 Rockefeller Plaza, New York 20, N. Y.
Explosives and Blasting Supplies

American Manganese Steel Division American Brake Shoe Co.
109 North Wabash Ave., Chicago 2, Ill.
Manganese Steel Castings, Power Shovel Dippers, Material Handling Pumps, Heat and Corrosion Resistant Castings, Reclamation and Hard-Facing Welding Materials

American Pulverizer Co.
1249 Macklind Ave., St. Louis 10, Mo.
Manufacturers of Ring Crushers and Hammermills for Primary and Secondary Crushing

American Steel & Wire Division
Rockefeller Bldg., 614 Superior Ave., N. W., Cleveland 13, Ohio
Wire Rope, Aerial Wire Rope Tramways, Electrical Wires and Cables, Welded Wire Fabric, Concrete Reinforcing, Wire Nails, Fencing, Netting

Atlas Powder Co.
Wilmington 99, Del.
Industrial Explosives and Blasting Supplies

Bacon-Greene & Milrov
29 Washington Ave., Hamden 14, Conn.
"FARREL-BACON" Jaw Crushers for Primary and Secondary Operations, Conveyors, Elevators, Rolls, Screens

Bacon-Pietsch Co., Inc.
75 North Maple Ave., Ridgewood, N. J.
Manufacturers of Farrel-Bacon Crushers and Allied Screening and Conveying Equipment

Baldwin-Lima-Hamilton Corp. Construction Equipment Division
South Main St., Lima, Ohio
Power Shovels, Draglines, Cranes, Bins, Conveyors and Idlers, Crushers and Pulverizers, Feeders, Plants—Crushing and Portable, Washing Equipment

Barber-Greene Co.
631 West Park Ave., Aurora, Ill.
Portable and Permanent Belt Conveyors, Belt Conveyor Idlers, Bucket Loaders both Wheel and Crawler Mounted, Asphalt Mixers and Finishers, Coal Handling Machines

Buchanan, C. G., Crushing Machinery Division, Birdsboro Steel Foundry and Machine Co.
1941 Furnace St., Birdsboro, Pa.
Primary, Secondary, and Finishing Crushers and Rolls

Bucyrus-Erie Co.
South Milwaukee, Wis.
Excavating, Drilling and Material Handling Equipment

Buda Co.
154th St. and Commercial Ave., Harvey, Ill.
Diesel and Gasoline Engines; Material Handling Equipment; Lifting Jacks; Earth Drills and Maintenance of Way Equipment

Caterpillar Tractor Co.
Peoria 8, Ill.
Track-Type Tractors, Bulldozers, Earthmoving Scrapers, Motor Graders, Heavy-Duty Off-Road Hauling Units, Diesel Engines, and Diesel Electric Generating Sets

Chain Belt Co.
P. O. Box 2022, Milwaukee 1, Wis.
Rex Conveyors, Elevators, Feeders, Idlers; Drive and Conveyor Chains, Power Transmission Equipment; Concrete Mixers, Pavers, Pumpcrete and Portable Pumps

Clark Equipment Co. Construction Machinery Division
270 Miller St., Benton Harbor, Mich.
Truck Mounted and Crawler Shovel Crane, 3/8 and 1/2 Cu. Yd.

Continental Gin Co.
4500 Fifth Ave., S., Birmingham 2, Ala.
Conveyors—Belt, Screw, Flight and Underground Mine; Elevators—Bucket and Screw; Feeders—Apron, Belt, Reciprocating, Table, and Screw; Drives—V-Belts, Chains and Sprockets, Gears and Speed Reducers

Cross Engineering Co.
P. O. Box 16, Carbondale, Pa.
Screen Plates and Sections, Perforated Plate for Vibrating, Rotary and Shaking Screens

Cummins Engine Co., Inc.
Fifth and Union Sts., Columbus, Ind.
Lightweight Highspeed Diesel Engines (50-550 Hp.) for: On-Highway Trucks, Off-Highway Trucks, Buses, Tractors, Earthmovers, Shovels, Cranes, Industrial and Switcher Locomotives, Air Compressors, Logging Yarders and Loaders, Oil Well Drilling Rigs, Centrifugal Pumps, Generator Sets and Power Units, Work Boats and Pleasure Craft

Manufacturers Division—National Crushed Stone Association
(continued)

Deister Machine Co.
1933 East Wayne St., Fort Wayne 4, Ind.
Deister Plat-O Vibrating Screen, Deister Compound Funnel Classifier

Detroit Diesel Engine Division General Motors Corp.
13400 West Outer Drive, Detroit 28, Mich.
Light Weight, Compact 2 Cycle Diesel Engines and "Package Power" Units for All Classes of Service

Diamond Iron Works, Inc.
1728 North Second St., Minneapolis 11, Minn.
Jaw and Roll Crushers; Vibrator, Revolving, and Scrubber Screens; Drdg Washers; Bucket Elevators; Belt Conveyors; Bins; Apron and Plate Feeders; Portable Gravel and Rock Crushing, Screening, and Washing Plants; Stationary Crushing, Screening, and Washing Plants; Hammermills

Du Pont, E. I., de Nemours & Co., Inc.
Wilmington 98, Del.
Explosives and Blasting Accessories

Eagle Iron Works
129 Holcomb Ave., Des Moines 13, Iowa
Fine Material Screw Washers—Classifiers—Dehydrators; Coarse Material Screw and Log Washers—Dewaterers; Water Scalping and Fine Material Settling Tanks; and "Swintek" Screen Chain Cutter Dredging Ladders

Easton Car & Construction Co.
Easton, Pa.
Off-Highway Transportation: Dump Trailers, Truck Bodies, and Cars for Mines, Quarries, and Earth Moving Projects

Ensign-Bickford Co.
Simsbury, Conn.
Primacord-Bickford Detonating Fuse and Safety Fuse

Euclid Road Machinery Co.
1361 Chardon Road, Cleveland 17, Ohio
Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation, Single and Twin Engine Earth Moving Scrapers

Even Spread Co.
P. O. Box 98, Owensville, Ohio
Power Spreaders and Attachments for Agricultural Lime and Fertilizer

Frog, Switch & Mfg. Co.
Carlisle, Pa.
Manganese Steel Department—Manufacturers of "Indian Brand" Manganese Steel Castings for Frogs, Switches, and Crossings, Jaw and Gyratory Crushers, Cement Mills, Mining Machinery, Etc., Steam Shovel Parts

General Electric Co.
1 River Road, Schenectady 5, N. Y.
Electric Motors, Controls, Locomotives, Coordinated Electric Drives for: Shovels, Drag Lines, Conveyors, Hoists, Cranes, Crushers, Screens, Etc.; Coordinated Power Generating and Distributing Systems Including Turbine Generators, Switchgear, Transformers, Cable, Cable Skids, Load Center Substations

Gill Rock Drill Co.
Lebanon, Pa.
Well Drill Tools and Supplies

Goodrich, B. F., Co.
500 South Main St., Akron 18, Ohio
Industrial Rubber Products — Flexible Bonded Edge Conveyor and Elevator Belting, Cord Conveyor Belting, Highflex and Cord Transmission Belting; Grommet V-Belts; Type 54 Air Hydraulic Control, Burst Proof Steam, Water, Suction and Other Hose; Armorite Chute Lining; Rubber and Koroseal Protective Clothing and Footwear; Tires and Tubes (Automobile, Truck, Off-the-Road, Industrial), Batteries

Goodyear Tire & Rubber Co., Inc.
Akron 16, Ohio
Airfoam; Mechanical Goods—Belting (Conveyor, Elevator, Transmission), Hose (Air, Water, Steam, Suction, Miscellaneous), Chute Lining (Rubber); Rims (Truck and Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road, LifeGuard, Safety Tubes, Puncture Seal Tubes)

Gruendler Crusher and Pulverizer Co.
2915 North Market St., St. Louis 6, Mo.
Rock and Gravel Crushing and Screening Plants, Jaw Crushers, Roll Crushers, Hammermills, Lime Pulverizers

Gulf Oil Corp. Gulf Refining Co.
Gulf Bldg., Pittsburgh 19, Pa.
Lubricating Oils, Greases, Gasoline and Diesel Fuels

Haiss, George, Mfg. Co., Inc., Division of Pettibone Mulliken Corp.
5720 Empire State Bldg., New York 1, N. Y.
Bucket Loaders, Buckets, Portable and Stationary Conveyors, Car Unloaders

Harnischfeger Corp.
4400 West National Ave., Milwaukee 14, Wis.
A complete line of Power Excavating Equipment, Overhead Cranes, Hoists, Smootharc Welders, Welding Rod, Motors and Generators, Diesel Engines

HarriSteel Products Co.
420 Lexington Ave., New York 17, N. Y.
Woven Wire Screen Cloth

Manufacturers Division—National Crushed Stone Association
(continued)

Hayward Co.
50 Church St., New York 7, N. Y.
Orange Peel Buckets, Clam Shell Buckets, Electric Motor Buckets, Automatic Take-up Reels

Heidenreich, E. Lee, Jr.
Consulting Engineers
75 Second St., Newburgh, N. Y.
Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals—Plant and Property

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Open Steel Floor Grating

Hercules Powder Co.
Wilmington 99, Del.
Explosives and Blasting Supplies

Hetherington & Berner Inc.
701-745 Kentucky Ave., Indianapolis 7, Ind.
Asphalt Paving Machinery, Sand and Stone Dryers, Dust Collectors

Hewitt-Robins Incorporated
666 Glenbrook Road, Stamford, Conn.
Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shake-outs; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants

Hughes Tool Co.
P. O. Box 2539, Houston 1, Texas
Drills and Drilling Equipment

Illinois Powder Mfg. Co.
506 Olive St., St. Louis 1, Mo.
Gold Medal Explosives

Ilyus, Edmund Burwell
Consulting Engineer
15 Franklin Road, S. W., Roanoke, Va.
Surveys, Appraisals, Reports and Design of Rock, Sand, Gravel, Ore, and Coal Plants and Materials Handling

Ingersoll-Rand Co.
11 Broadway, New York 4, N. Y.
Rock Drills, Quarrymaster Drills, Jackbits, Bit Reconditioning Equipment, Portable and Stationary Air Compressors, Air Hoists, Slusher Hoists, Air Tools, Diesel Engines, Pumps

Insley Manufacturing Corp.
801 North Olney St., Indianapolis 6, Ind.
Concrete Carts and Buckets, ½ Yd. Cranes and Shovels

International Harvester Co.
180 North Michigan Ave., Chicago 1, Ill.
Motor Trucks, Diesel and Gasoline Power Units; Crawler Tractors; Industrial Wheel Tractors

Iowa Manufacturing Co.
916 16th St., N.E., Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Hot and Cold Mix Asphalt Plants, Stabilizer Plants, KU-BIT Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills, Bins

Jaeger Machine Co.
550 West Spring St., Columbus 16, Ohio
Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers

Jaite Co.
Jaite, Ohio
Multiwall Paper Bags, Sewn and Pasted Style for Packaging Lime, Cement, Plaster, Etc.

Jeffrey Manufacturing Co.
East First Ave., Columbus 16, Ohio
Material Handling Machinery, Crushers, Pulverizers, Screens, Chains

Johnson-March Corp.
1724 Chestnut St., Philadelphia 3, Pa.
Dust Allaying Equipment

Joy Manufacturing Co.
333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.
Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists; Multi-Purpose and Portable Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; Drill-Bit Furnaces; "Spaders"; "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core

Kennedy-Van Saun Mfg. & Eng. Corp.
2 Park Ave., New York 16, N. Y.
Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel Co.
505 Kensington Ave., Chicago 28, Ill.
Manganese Steel Castings, Dipper Teeth, Crawler Treads, Jaw Plates, Concaves and Hammers

King Powder Co., Inc.
Cincinnati, Ohio
Detonite, Dynamites, and Blasting Supplies

Koehring Co.
3026 West Concordia Ave., Milwaukee 16, Wis.
Excavating, Hauling and Concrete Equipment

Manufacturers Division—National Crushed Stone Association
(continued)

Le Roi Co.
Cleveland Rock Drill Division
12500 Berea Road, Cleveland 11, Ohio
Air Compressors—Portable 60 Cfm. to 600 Cfm. Gas or Diesel; Tractairs—Combined Tractor with 105 Cfm. Air Compressor; Engines; Generator Sets; Rock and Wagon Drills; Jumbo Drill Rigs, Drifters, Stopers, Self Propelled Drill Rigs

Linde Air Products Co., Division of Union Carbide and Carbon Corp.
30 East 42nd St., New York 17, N. Y.
Oxygen, Acetylene Welding Equipment and Supplies

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, Speed-O-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Ludlow-Saylor Wire Cloth Co.
634 South Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, All Commercial Alloys and Metals

Mack Motor Truck Corp.
350 Fifth Ave., New York 1, N. Y.
On- and Off-Highway Trucks, Tractor Trailers, Six-Wheelers, from 5 to 30 Tons Capacity, both Gasoline- and Diesel-Powered

Marion Power Shovel Co.
617 West Center St., Marion, Ohio
A Complete Line of Power Shovels, Draglines, and Cranes

McLanahan & Stone Corp.
200 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, etc.

Murphy Diesel Co.
5317 West Burnham St., Milwaukee 14, Wis.
Murphy Diesel Engines Ranging from 90 to 190 Continuous Horsepower at 1200 Rpm. and Packaged Type Generator Sets 60 to 133 Kw. for All Classes of Service

New York Rubber Corp.
100 Park Ave., New York 17, N. Y.
Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Nordberg Mfg. Co.
3073 South Chase Ave., Milwaukee 7, Wis.
Cone, Gyratory, Jaw and Impact Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens; Grizzlies; Diesel and Steam Engines; Compressors; Mine Hoists; Track Maintenance Tools

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 South LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels

Olin Industries, Inc.
Explosives Division
East Alton, Ill.
Dynamite, Black Powder, Blasting Caps, Blasting Supplies

Osgood Co.
Cheney Ave., Marion, Ohio
Power Shovels, Cranes, Draglines, Hoes, Etc., 3/8 to 2 1/2 Cu. Yd.

Pennsylvania Crusher Co.
Liberty Trust Bldg., Broad and Arch Sts., Philadelphia 7, Pa.
Single Roll Crushers, Impactors, Hammermills, Ring Type Granulators, KUE-KEN Jaw Crushers, KUE-KEN Gyracones, Dixie Non-Clog and Standard Hammermills

Pettibone Mulliken Corp.
4710 West Division St., Chicago 51, Ill.
Material Handling Buckets, Clamshells, Draglines, Pullshovels, Dippers, Shovel Dippers, Pumps, Hammermills, Front End Loaders, Bucket Conveyor Loaders, Fork and Bucket Loaders, Motor Graders, Manganese Steel Castings

Pioneer Engineering Works, Inc.
1515 Central Ave., N. E., Minneapolis 13, Minn.
Jaw Crushers, Roll Crushers (Twin and Triple), Vibrating and Revolving Screens, Feeders (Mechanical, Grizzly, Apron, and Pioneer-Oro), Belt Conveyors, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants

Pit and Quarry Publications, Inc.
431 South Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Quaker Rubber Corp.
Tacony and Milnor Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Rock Bit Sales and Service Co.
350 Depot St., Asheville, N. C.
Tungsten Carbide Detachable Bits, "Rock Bit" Drill Steel Inlaid with Tungsten Carbide, Carbon Hollow Drill Steel, Alloy Hollow Drill Steel

Manufacturers Division—National Crushed Stone Association
(concluded)

Rock Products
309 West Jackson Blvd., Chicago 6, Ill.

Rogers Iron Works Co.
11th and Pearl Sts., Joplin, Mo.
Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos and Underground Loaders

Screen Equipment Co., Inc.
1754 Walden Ave., Buffalo 25, N. Y.
SECO Vibrating Screens

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screen, Simplicity D'centegrator, Simplicity D'watering Wheel

SKF Industries, Inc.
Front St. and Erie Ave., P. O. Box 6731, Philadelphia 32, Pa.
Anti-Friction Bearings—Self-Aligning Ball, Single Row Deep Groove Ball, Angular Contact Ball, Double Row Deep Groove Ball, Spherical Roller, Cylindrical Roller, Ball Thrust, Spherical Roller Thrust; Pillow Block and Flanged Housings—Ball and Roller

Smith Engineering Works
532 East Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman Foundry & Machine Co., Inc.
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Talcott, W. O. & M. W., Inc.
91 Sabin St., Providence 1, R. I.
Belt Fasteners, Belt Lacing, Conveyor Belt Fasteners, and Patch Fasteners

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
Power Shovels, Cranes, Crawler Cranes, Locomotive Cranes, Draglines, Diesel Electric, Gasoline, 3/8 to 2 1/2 Cu. Yd. Capacities

Torrington Co.
Bantam Bearings Division
3702 West Sample St., South Bend 21, Ind.
Anti-Friction Bearings; Roller Bearings: Spherical, Tapered, Straight, Ball, Needle

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 North 7th St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N. E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers and Tyler Standard Screen Scale Sieves

Universal Engineering Corp.
625 C Ave., N. W., Cedar Rapids, Iowa.
Jaw Crushers, Roll Crushers, Hammermills, Complete Crushing, Screening, and Loading Plants, Either Stationary or Portable for Stone Aggregates or Aglime, Portable and Stationary Washing Plants, Asphalt Plants, and Impact Breakers

Vibration Measurement Engineers
7665 Sheridan Road, Chicago 26, Ill.
Specialists in Blasting Complaint Investigations; Seismological Surveying; Expert Testimony in Blasting Litigation

Werco Steel Co.
2151 East 83rd St., Chicago 17, Ill.
Crusher Jaws, Roll Shells, Mantles, Bowl Liners, Conveyor and Elevator Chain, All Types Wear Resistant Steel Manganese and Alloy Steel Castings, Screen Plate—Perforated Steel, Screen Sections and Decks

Weston Dump Body Co.
326 S.W. 11th St., Des Moines 9, Iowa
Combination Lime, Sand, and Gravel Body; Special Bodies for Quarry and Pit Work

White Motor Co.
842 East 79th St., Cleveland 1, Ohio
On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines, Power Units, Axles, Special Machine Assemblies; All Classes of Service